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A Review of Research on Marine Main Propulsion Systems

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Abstract: Ship power, as an essential component of ship engineering, directly affects the navigation performance, economy, and environmental friendliness of ships. This article reviews the development history of ship power, introduces the main propulsion devices including internal combustion engines, steam engines, and electric motors, and discusses the structure and optimization design of ship power systems. Modern ship power technology includes traditional diesel and gasoline engines, as well as new power devices such as liquefied natural gas (LNG) engines, hybrid power systems, and fuel cells. Electric ships are gaining attention due to their efficiency and environmental benefits. In the future, ship power technology will develop towards green environmental protection, intelligence, integration, diversification, and digitization, providing more reliable and efficient power support for the shipping industry and the advancement of ship engineering.

Keywords: Ship Power; Internal Combustion Engine; Steam Engine; Electric Motor; Intelligence; Ship Engineering.

1. Introduction

Ship power, as an essential component of ship engineering, directly affects the navigation performance, economy, and environmental friendliness of ships [1]. With the growth of global trade and the development of the shipping industry, ship power technology has also been continuously innovated and improved [2]. Traditional ship power plants mainly include internal combustion engines and steam engines [3]. In recent years, however, electric ships, as a new type of ship power form, have gradually gained attention and promotion. The development of ship power technology is not only related to the economic benefits and safety of ships, but also to the protection of the marine environment and sustainable development. Therefore, in-depth research on ship power technology and exploration of efficient, energy-saving, clean, and environmentally friendly ship power plants and systems are of great significance for promoting the progress of ship engineering technology and improving the competitiveness and sustainable development capabilities of ships. This article will review the development history, main power plants, the structure and optimized design of the power system of ships, aiming to provide references and insights for related research and engineering practices [4].

2. The Development History of Ship Power

The development of ship power has undergone a transformation from human power, wind power to mechanical power [5]. The development history of ship power can be traced back to ancient sailing ships and oar boats. The earliest ship power plants relied on wind power and human power to navigate. With the advent of the Industrial Revolution, the invention of the steam engine greatly advanced the development of ship power plants.

Steam power system is one of the earliest forms of ship power systems, using steam engines to generate power. However, due to the rising prices of coal and oil, the use of steam power systems has gradually decreased. Diesel power systems have become the mainstream type of ship power systems, using diesel engines to generate power, and providing higher efficiency and lower operating costs. Additionally, turbine power systems, as the latest type of ship power system, have been widely applied in large ships [6].

In recent years, with the development of electric power technology and electric transmission technology [7], the application of electric motors in ship power has become increasingly widespread, becoming one of the important forms of ship power.

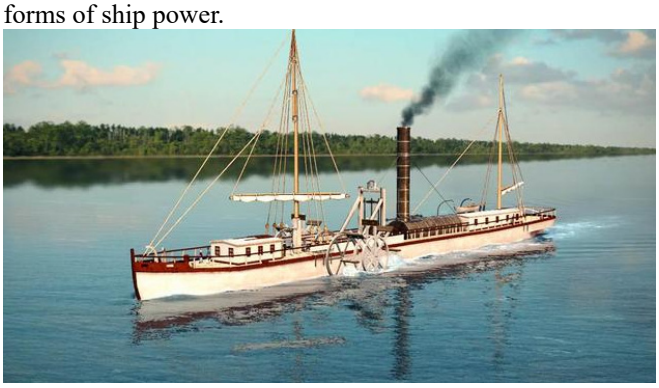

Figure 1. Steam-powered ship

Figure 2. Internal combustion engine ship

Figure 3. Electric-powered ship

3. Main Power Plants

3.1. Steam Engine

Steam engines, as an important form of ship power, once played a crucial role in the history of maritime shipping. Their working principle is based on converting thermal energy into mechanical energy [8]. Fuel (such as coal) is burned to generate high-temperature steam, which expands in a closed container, driving the piston to perform reciprocating motion. This linear motion of the piston is then converted into the rotational motion of the ship's propeller through mechanisms such as connecting rods and crankshafts [9], thus propelling the ship forward.

Steam engines have significant advantages in the field of ship power. For instance, their working principle is based on thermal energy conversion, resulting in relatively high power output. Steam engines also have a relatively fast response speed [10], enabling quick adjustment of output power to adapt to different sailing conditions. Despite these advantages, the application of steam engines in ships has gradually decreased. This is mainly due to some inherent disadvantages of steam engines. Their structure is relatively complex, involving numerous valves, pipes, and mechanical equipment, making manufacturing, installation, and maintenance difficult. Steam engines consume a large amount of water and fuel during operation, and produce significant waste heat and exhaust gas, causing pollution to the environment.

3.2. Internal Combustion Engine

Internal combustion engines, especially diesel engines, have become an indispensable power plant in modern shipbuilding industry [11]. As one of the main power sources for ships, the working principle of diesel engines is based on the combustion of fuel in the cylinder, generating thermal energy that is converted into mechanical energy to propel the ship [12].

Diesel engines are widely used in the shipping industry due to their significant power advantages [13]. Large diesel engines can output extremely high torque and power, and they also have good fuel economy. Compared to other types of power plants, diesel engines have a lower fuel consumption rate, helping to reduce the operating costs of ships. Modern diesel engines are designed with sophisticated and compact structures, and their components are highly standardized, making maintenance and servicing relatively simple. In addition, diesel engines have a long service life and high reliability, enabling them to operate stably under harsh working conditions, reducing the risks caused by power failures in ships [14].

Figure 4. Internal combustion engine

Internal combustion engines also include gasoline engines [15], which are suitable for some small ships and high-speed boats, such as yachts and speedboats. These ships often need to accelerate or decelerate quickly in a short time to cope with complex sailing environments, and the high rotational speed and quick response ability of gasoline engines can meet these demands.

In addition to diesel engines and gasoline engines, some new power plants have emerged in the field of ship power. For instance, liquefied natural gas (LNG) engines, hybrid power systems, and fuel cells have gradually gained attention [16].

3.3. Electric Motor

As a new trend in ship power, electric motors are gradually changing the traditional way of ship propulsion. Their working principle is simple and efficient, converting electrical energy into mechanical energy to directly drive the movement of ships, bringing a brand-new sailing experience to ships.

Electric ships usually adopt battery packs or generators as their sources of electrical energy [17]. Battery packs are devices that store electrical energy, providing continuous and stable power for electric motors. Generators, on the other hand, can produce electrical energy by burning fuel or other energy sources, providing continuous power for electric ships. Meanwhile, with the continuous development and application of renewable energy technologies, such as solar energy and wind energy, they can also be used as energy sources for generators, further reducing the energy consumption and environmental pollution of ships.

Compared with traditional ships, electric ships have many advantages [18]. Firstly, the propulsion process of electric ships does not produce harmful gases and noise, causing minimal environmental pollution. Secondly, the maintenance cost of electric ships is lower because the structure of electric motors is relatively simple and the failure rate is low. In addition, electric ships have a fast response speed, enabling them to quickly adjust the magnitude and direction of propulsion force, improving the maneuverability and safety of ships.

With the continuous development and application of renewable energy technologies, electric ships will play an increasingly important role in the field of ship power [19].

Figure 5. Electric propulsion system

4. Future Development of Ship Power Technology

With the development of the shipping industry and the advancement of ship engineering technology, ship power technology is also constantly innovating and improving. The future development directions of ship power technology mainly include the following aspects:

Green Environmental Protection: Future ship power technology will pay more attention to green environmental protection, adopting clean energy and high-efficiency energy-saving technologies to reduce environmental pollution and energy consumption.

Intelligence: Future ship power technology will become more intelligent, adopting advanced control systems and sensor technology to achieve automated control and intelligent management of ship power systems.

Integration: Future ship power technology will become more integrated, integrating the ship's power system, control system, and navigation system to improve the overall performance and reliability of the ship.

Diversification: Future ship power technology will become more diverse, providing more personalized solutions for different types of ships and operating environments.

Digitization: Future ship power technology will become more digitized, adopting advanced information technology and communication technology to achieve remote monitoring and management of ship power systems, improving ship operating efficiency and safety.

5. Conclusion

Ship power is an essential component of ship engineering, directly affecting the navigation performance and energy utilization efficiency of ships. This article has reviewed the development history, main power plants, and power systems of ship power, introduced several common power plants such as internal combustion engines, steam engines, and electric motors, and looked forward to the future development directions of ship power technology [20]. It is believed that with the continuous advancement of technology, ship power technology will become more intelligent, green, and diverse, providing more reliable and efficient power support for the development of the shipping industry and the progress of ship engineering.

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